# UNITED STATES PATENT AND TRADEMARK OFFICE

I, Susan ANTHONY BA, ACIS,

Director of RWS Group Ltd, of Europa House, Marsham Way, Gerrards Cross, Buckinghamshire, England declare;

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2. That the translator responsible for the attached translation is well acquainted with the French and English languages.

3. That the attached is, to the best of RWS Group Ltd knowledge and belief, a true translation into the English language of the specification in French filed with the application for a patent in the U.S.A. on

under the number

4. That I believe that all statements made herein of my own knowledge are true and that all statements made on information and belief are true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the patent application in the United States of America or any patent issuing thereon.

For and on behalf of RWS Group Ltd

The 27th day of January 2006

# Module for cooling the charge air and recirculated exhaust gases of an internal combustion engine of a motor vehicle

The invention relates to internal combustion engine motor vehicles.

It relates more particularly to a cooling module consisting of a charge air cooler and of a recirculated exhaust gas cooler, the charge air cooler comprising a heat exchange bundle for cooling the charge air, an inlet header box for the air that is to be cooled immediately adjacent to an inlet end of the charge air cooler heat exchange bundle and an outlet header box for the cooled air immediately adjacent to an outlet end of the charge air cooler heat exchange bundle, the recirculated exhaust gas cooler comprising a heat exchange bundle for cooling the recirculated exhaust gases, an inlet header box for the recirculated exhaust gases which is immediately adjacent to an inlet end of the recirculated exhaust gas cooler heat exchange bundle and an outlet header box for the recirculated exhaust gases immediately adjacent to an outlet end of the recirculated exhaust gas cooler heat exchange bundle, a wrapper housing the charge air cooler heat exchange bundle and the recirculated exhaust gas cooler heat exchange bundle.

In order to increase the specific power of motor vehicle combustion engines, it is known practise for them to be supplied with charge air that has been compressed using a compressor driven by the exhaust gases. However, this compression has the effect of raising the charge air to a high temperature. For this reason, the charge air has to be cooled before it is introduced into the combustion chambers of the engine. This cooling is performed in the conventional way in an

air cooler known as a charge air cooler or intercooler.

Furthermore, in order to meet increasingly tight pollution standards, it is known practise for some of the exhaust gases to be recirculated and mixed with the fresh inlet gases in order to lower the combustion temperature in the engine. However, these recirculated exhaust gases are at a high temperature which may be as high as about 500°C, which means that they too have to be cooled. Conventionally, this cooling is done by passing them through a recirculated exhaust gas cooler.

In order to reduce the space occupied by these two coolers it is common practise for them to be housed in a single unit (DE 19 853 455). That document describes a module consisting of a charge air cooler housed in a unit and of a recirculated exhaust gas cooler mounted on the charge air cooler. The main feature of this module is that there is a funnel-shaped device positioned at the interface between the charge air and recirculated gas outlets. The recirculated exhaust gas outlet is downstream of the charge air outlet.

However, assembly of a cooling module of this type is done using conventional mechanical means such as screws or bolts. It therefore entails a significant number of operations which take time and increase the cost of manufacture of the module.

Furthermore, in order to meet increasingly tight pollution standards, a need to have more precise control over the temperature of the mixture of inlet air and recirculated gases admitted to the engine is now felt.

The invention is aimed specifically at a cooling module that meets these objectives. The first of these objectives is achieved through the fact that the charge air cooler heat exchange bundle and the recirculated

exhaust gas cooler heat exchange bundle are assembled in a single brazing operation and in that they are also assembled with one another during this same brazing operation.

All or some of the components of the module, especially the bundles of each of the coolers, can thus be made of a single material, for example aluminum and/or an aluminum alloy.

Advantageously, the wrapper housing the heat exchange bundles of the charge air cooler and of the recirculated exhaust gas cooler is assembled with these bundles during the single brazing operation during which these bundles are assembled with one another. In particular, the wrapper is made of the same single material, for example aluminum and/or an aluminum alloy, as the cooler bundles.

By virtue of this feature, assembling the cooling module can be done in a single operation and without the need to resort to mechanical means of assembly such as screws or bolts. It is therefore quicker to manufacture and its cost price is lower.

According to a first embodiment, the wrapper comprises a first and a second peripheral rim which protrude on each side of the charge air cooler bundle, the charge air cooler inlet header box being assembled with one of these peripheral rims, the charge air cooler outlet header box being assembled with the other of these peripheral rims.

In this embodiment, the inlet and outlet header boxes of the charge air cooler are attached after the brazing operation has been performed. They can therefore be produced by molding in a different material, for example in plastic.

According to another embodiment, the dimensions of the wrapper are chosen such that they delimit a first and a second empty space, one at the inlet end and one at the outlet end of the charge air cooler heat exchange bundle, the first and second empty spaces respectively constituting an inlet header box and an outlet header box for the charge air.

In this embodiment, the cooling module is entirely assembled in a single operation, including the inlet and outlet header boxes delimited by the wrapper itself. The module is then produced in a single material, for example an aluminum alloy.

In an advantageous embodiment, the wrapper comprises two half-casings. These two half-casings may be able to slide one with respect to the other in order to accommodate variations in height of at least one of the heat exchange bundles.

When the inlet and outlet header boxes of the charge air cooler are added on, each of the two half-casings advantageously has a U-shaped cross section comprising an end wall and two lateral edges situated one on each side of the end wall, the lateral edges of one of the half-casings sliding with respect to the lateral edges of the other half-casing.

When the cooling module is made entirely in aluminum, each of the two half-casings advantageously has the shape of a container comprising a peripheral rim, the peripheral rim of one half-casing being able to fit into the peripheral rim of the other half-casing and to slide with respect to the latter.

Whatever the embodiment, the wrapper may, in one particular embodiment, comprise a pressed housing which accommodates the recirculated exhaust gas cooler bundle.

In another embodiment, the wrapper comprises a separate charge air cooler casing, this separate casing being brazed in a single operation to one of the two half-casings during the single brazing operation during which the bundles are assembled with one another.

One of the half-casings may advantageously comprise an end wall that is taller to make it easier to install the recirculated exhaust gas cooler.

Finally, according to another advantageous feature of the invention, the cooling module comprises a passage for the recirculated exhaust gases which opens directly into the outlet header box of the charge air cooler, the cross section of this passage being equal to or greater than the cross section of the recirculated exhaust gas cooler bundle.

By virtue of this feature, the inlet air and the recirculated gases are indeed mixed upstream of the inlet ducts. The gases can mix and their temperature can therefore even out, so that the temperature of the mixture is lowered.

Furthermore, the fact that the passage cross section for the recirculated exhaust gases can be at least equal to the cross section of the recirculated exhaust gas cooler bundle allows these gases not to experience any pressure drop and improves the uniformity of the mixing.

Other features and advantages of the invention will become further apparent from reading the description which follows of some exemplary embodiments which are given by way of illustration with reference to the attached figures. In these figures:

- figure 1 is an external perspective view of a first embodiment of a cooling module according to the

invention;

- figure 2 is an exploded view, minus the header boxes, of the module depicted in figure 1;
- figure 3 is a view of the module of figures 1 and 2 in cross section on a plane passing through the center of the exhaust gas inlet flange;
- figure 4 is a view of the cooling module in longitudinal section on a plane passing through the axis of one of the cooling water ducts;
- figure 5 is a detailed view in section illustrating the structure of the charge air cooler heat exchange bundle;
- figure 6 is a perspective exterior view of a variant embodiment of the module of figure 1;
- figure 7 is a perspective view, minus header box, of the module of figure 6;
- figure 8 is an exploded perspective view of the module of figures 6 and 7;
- figure 9 is an exterior view in perspective of a second embodiment of a cooling module according to the invention comprising added-on header boxes;
- figure 10 is a perspective view from beneath of the module of figure 9;
- figure 11 is a perspective view, minus header box, of the module of figures 9 and 10;
- figure 12 is a view of the module of figure 9 in longitudinal section on a plane passing through the axis of one of the cooling water ducts;
- figure 13 is a view in cross section on a plane passing through the axis of the recirculated exhaust gas inlet flange;
- figure 14 is an exterior perspective view of a cooling module according to the invention, made entirely in aluminum;
- figure 15 is a view from above of the cooling module of figure 14;
- figure 16 is a view in section on XVI-XVI of figure 15;
- figure 17 is a view in section on XVII-XVII of

figure 15; and

- figure 18 is a view in section on XVIII-XVIII of figure 15.

The cooling module of the invention is intended to equip a motor vehicle having an internal combustion engine comprising two cooling circuits: a high-temperature first circuit for cooling the combustion engine and a low-temperature second circuit for cooling certain vehicle equipment items. This module consists of a charge air cooler and of a recirculated exhaust gas cooler. Each of these coolers itself consists of a heat exchange bundle, of an inlet header box immediately adjacent to an inlet end of the heat exchange bundle and an outlet header box immediately adjacent to an outlet end of the heat exchange bundle. The gas to be cooled, namely the charge air or the recirculated exhaust gases, is introduced into the inlet header box of the cooler. It passes through the heat exchange bundle giving up heat to a cooling fluid, generally the water of the low-temperature circuit, then opens into the outlet header box.

In the example depicted in figures 1 to 5, the charge air cooler bundle is denoted by the general reference 2 and the recirculated exhaust gas cooler bundle is denoted by the general reference 4. The bundles 2 and 4 are separated from one another by an interface plate 5 (figure 2).

In order to reduce the space required by the module, as previously explained, the bundles 2 and 4 are housed inside a common wrapper 6. In the embodiment of figures 1 to 5, the wrapper 6 consists of two half-casings, namely a first half-casing 7 and a second half-casing 8. Each half-casing 7, 8 has a very elongate U-shaped cross section comprising an end wall 10 and two lateral edges 12 situated one on each side of the end wall 10. The lateral edges 10 of the half-casings 7 and 8 are

able to slide one with the other in such a way as to adjust the height of the wrapper 6 to accommodate dimensional variations in the heat exchange bundles 2 and 4. This is because, as a result of manufacturing tolerances, the height of these bundles may vary slightly.

One of the two half-casings, in this instance the half-casing 8, has a housing 14, made for example by pressing and intended to accommodate the recirculated exhaust gas cooler bundle 4. As can be seen more specifically in figure 4, in one of its dimensions, directed along the longest dimension of the heat exchange bundle 4, the housing 14 is dimensioned in such a way as to fit the length of the bundle 4. By contrast, as can be seen more particularly in figure 3, in its other dimension, directed along the width of the heat exchange bundle 4, the housing 14 is dimensioned in such a way as to form an empty space 16 at the inlet end 17 of the bundle 4 and an empty space 18 at the outlet end 19 of this same bundle. The empty spaces 16 and 18 thus respectively constitute an inlet header box 16 and an outlet header box 18 for the recirculated exhaust gas cooler.

An inlet flange 20 is connected to an inlet duct 22 which opens into the inlet header box 16 (figure 3). The flange 20 is for the connection of an inlet pipe (not depicted) carrying the exhaust gases that are to be cooled. An inlet duct 24 and an outlet duct 26 are also provided on the housing 14 of the half-casing 8. The ducts 24 and 26 respectively let a cooling fluid, generally the water of the low-temperature circuit, in to an out of the recirculated exhaust gas cooler bundle 4 and the charge air cooler bundle 2. In the module depicted, the channels along which the cooling fluid circulates through the bundles 2 and 4 are connected in parallel. In other words, the ducts 24 and 26 are common to the two bundles, thus reducing the number of

external connections to be made.

The cooling module depicted in figures 1 to 5 further comprises an inlet header box 30 and an outlet header box 32 for the charge air. Unlike the header boxes 16 and 18 of the recirculated exhaust gas cooler, the inlet 30 and outlet 32 header boxes of the charge air cooler are not directly delimited by the wrapper 6 but are added on. That allows them to be made of a material that differs from that of the wrapper 6 and of the heat exchange bundles 2 and 4, for example of plastic. The inlet header box comprises an inlet duct 34 and the outlet header box an outlet duct 36. The charge air enters the inlet header box via the duct 34 as depicted schematically by the arrow 38, passes through the heat exchange bundle 2, then opens into the outlet header box 32 before leaving the heat exchange module in the outlet duct 36 as depicted diagrammatically by the arrow 40.

To allow the inlet and outlet header boxes of the charge air cooler to be fixed to the wrapper 6, each of the two half-casings 7 and 8 has a first and a second peripheral rim which protrude on each side of the charge air cooler bundle 4. Advantageously, grooves (not depicted) are formed in the feet of the header boxes 30 and 32. These grooves fit onto the peripheral rims of the half-casings 7 and 8. The header boxes may be fixed to the wrapper by any appropriate means, for example adhesive bonding.

As can be seen more particularly in figure 5 which depicts a detailed view in section of the charge air cooler heat exchange bundle 2, each of the heat exchange bundles 2 and 4 consists of a stack of plates 42 between which there are corrugated inserts 44 constituting heat-exchange surfaces which improve the exchange of heat between the charge air that is to be cooled and the plates. Each plate is of roughly

rectangular shape having two short sides and two long sides. Each plate comprises an end wall 46 bounded by a peripheral rim 48. Ribs 50 may be provided in the end wall 46 of each of the plates to delimit circulation passages for the cooling fluid (figure 2).

The end wall 46 and the peripheral rim 48 determine a shallow dish. The plates are grouped together in pairs assembled by their peripheral rim 48. Thus, the dish of the top plate and the dish of the bottom plate belonging to the same pair of plates combine to form a channel 52 through which the cooling fluid can circulate. Furthermore, two bosses 54 are formed along a short side of each of the plates. The bosses of a pair of plates press against the bosses of the adjacent plate pairs. This then produces an inlet manifold and an outlet manifold for the cooling fluid. The cooling fluid enters the bundle as depicted diagrammatically by the arrow 56 then flows through the circulation channels 52 as depicted diagrammatically by the arrows 58. The fluid leaves the heat exchange bundle 2 in the opposite direction.

The bosses 54 of two pairs of plates also between them determine circulation channels 60 for the charge air of the charge air cooler and for the exhaust gases of the exhaust gas cooler. Turbulence generators 44 are positioned in the circulation passages 60.

As regards the recirculated exhaust gas cooler bundle 4 more particularly, each circulation channel for the exhaust gases that are to be cooled may advantageously lie between two channels for the circulation of the cooling liquid. By virtue of this feature, the wall of the pressed housing 14 and the interface plate 5 are not in direct contact with the gases that are to be cooled, the temperature of which may be very high (500°C). On the contrary, these walls are cooled by the circulation of the cooling liquid. Their temperature is

thus considerably lowered by comparison with the wall temperature of a conventional recirculated exhaust gas cooler. It may for example be of the order of 200°C. These walls can therefore be made in a material with less resistance to temperature, such as aluminum. This advantage is considerable because aluminum is easier to work and less expensive than stainless steel.

As can be seen more specifically in figure 3, the empty space 18 formed in the housing 14, which constitutes the outlet header box for the recirculated exhaust gas cooler is in direct communication with the interior space 70 of the outlet header box 32 of the charge air cooler. In consequence, the cross section of the passage offered to the cooled recirculated exhaust gases is the cross section of the outlet header box 18. This cross section is equal to the cross section of the exhaust gas cooler bundle 4. These exhaust gases can therefore arrive in the charge air cooler outlet header box 32 without their flow being retarded. In particular, they do not have to negotiate any passage of narrowed cross section which would incur a pressure drop.

Figures 6 to 8 depict a variant embodiment of the cooling module of figures 1 to 5. The overall construction of the cooler of figures 6 to 8 is identical to that of the first embodiment. In consequence, the same elements have been denoted by the same reference numerals. The difference lies in the fact that the pressed housing 14 in the half-casing 8, instead of having a width equal to the longest dimension of the plates of the heat exchange bundle 4 of the recirculated exhaust gas radiator, has a part 72 of enlarged cross section. In the example, the enlarged section 72 extends over the entire length of the cooling module. In other words, its length is equal to the length of the plates of the charge air cooler heat exchange bundle 2, this length also corresponding to

the length of the outlet header box 32 of this cooler.

As a result, in this embodiment, the passage cross section offered to the recirculated exhaust gases once they have passed through the cooler bundle 4 is not equal to but greater than the cross section of the heat exchange bundle 4. This feature allows for better mixing of the recirculated exhaust gases with the fresh gases from the outlet header box 32. What happens is that as soon as they leave the heat exchange bundle 4, the recirculated exhaust gases can spread over the entire length of the cooling module. As a result, they mix with all of the charge air rather than preferentially with the charge air lying on the same side as the exhaust gas cooler.

Figures 9 to 13 depict a third variant embodiment of the cooling module of the invention. In these figures, the same elements bear the same reference numerals as in the preceding figures. The module of figures 9 to 13 differs through the presence of a separate casing for the recirculated exhaust gas cooler bundle 4. Whereas, in the previous two embodiments, the bundle 4 of the exhaust gas cooler was housed in a housing 14 pressed directly in the half-casing 8, in this embodiment, the bundle 4 is housed in a casing 76 designed as a separate part and added on to the half-casing 8. The casing 76 can be fixed to the half-casing 8 by any means within the competence of the person skilled in the art. However, the casing 76 is preferably assembled by brazing in a single operation. In other words, the single brazing operation during which the bundles 2 and 4 of the coolers are assembled and during which these bundles are assembled with one another and with the wrapper 6 (consisting of the two half-casings 7 and 8 in the examples) is put to use for assembling the separate casing 76 with the half-casing 8. Thus, the presence of this additional part does not entail any additional operation for assembling the cooling module,

except that of positioning the casing 76 on the half-casing 8. The inlet duct 24 and the outlet duct 26 for the cooling fluid are provided on the separate casing, as is the recirculated exhaust gas inlet duct 78.

The added-on casing 76 may be made of the same material as the wrapper 6 or of a different material. However, if the casing 76 is to be assembled by brazing in a single operation, it is preferable for the materials to be the same.

Just as for the pressed housing 14, the separate casing 76 has a long dimension (its length) which corresponds to the length of the plates of the exhaust gas cooler heat exchange bundle 4. By contrast, its short dimension (its width) is greater than the short dimension of the plates of the bundle 4 so as to delimit an empty space 16 at an inlet end of the bundle 4 and an empty space 18 at an outlet end of this same bundle. The empty spaces 16 and 18, as before, respectively constitute an inlet header box and an outlet header box for the recirculated exhaust gases. An interface plate 5 separates the charge air cooler bundle 2 from the exhaust gas cooler bundle 4. The interface plate closes off the inlet and outlet header boxes 16 and 18. One or more perforations 79, forming communication passages, are formed in the interface plate 5 to place the outlet header box 18 in communication with the internal volume of the outlet header box 32 of the charge air cooler (see figure 13).

The embodiment of figures 9 to 13 also differs in that one of the two half-casings, in this instance the half-casing 8, comprises an end wall 10 the width of which exceeds that of the end wall of the other half-casing, the half-casing 7 in this example. This arrangement is advantageous because it offers even more space for installing the recirculated exhaust gas cooler. In particular, when the cooling module comprises an added-

on separate casing 76, it is necessary to provide, at the periphery of this casing, an empty region so that the contacting surfaces of the casing 76 and of the end wall 10 can be brazed. The fact of increasing the width of the end wall also allows the inlet header boxes 16 and 18 to be more generously sized.

It is pointed out that, in this embodiment, the passage 79 which places the outlet header box 18 of the exhaust gas cooler in communication with the internal volume of the outlet box 32 of the charge air radiator has a passage cross section roughly equal to the cross section of the bundle 4. It goes without saying that, according to a variant embodiment, this passage cross section could be enlarged so that it extends over the entire length of the plates of the charge air cooler bundle 2, as was described with reference to figures 6 to 8. To achieve that, all that would be required would be a modification to the shape of the added-on casing 76, equipping it with an extension 72 similar to the extension of the pressed housing 14 of figures 6 to 8.

Figures 14 to 18 depict a fourth variant embodiment of the cooling module of the invention. This embodiment is characterized in that it comprises no added-on inlet and outlet header boxes 30, 32 for the charge air cooler. What happens is that these header boxes are formed directly by empty spaces positioned on each side of the charge air radiator heat exchange bundle 2.

Each half-casing 7, 8 has an end wall 10 that is generally flat and of square or rectangular shape, and four lateral walls 80 connected to the end wall 10 by a fillet and approximately perpendicular to this wall. The lateral walls 80 of the two half-casings fit together in such a way as to allow the two half-casings to slide one relative to the other in order to accommodate slight variations in height of the bundles 2 and 4. A charge air inlet duct 82 is provided on the

half-casing 7 and a charge air outlet duct 84 is provided on the half-casing 8.

As can be seen in particular in figure 16, the charge air enters the cooling module via the inlet duct 82 as depicted schematically by the arrow 86. It reaches the inlet header box 88 then passes through the charge air cooler heat exchange bundle 2 exchanging heat with the cooling water. Having passed through the bundle 2, the cooled charge air reaches the outlet header box 90 then leaves the cooling module via the duct 84 as depicted schematically by the arrow 92. The recirculated exhaust gases enter the cooling module via the flange 20, as depicted schematically by the arrow 94; they pass right through the heat exchange bundle 4 and emerge directly, as depicted schematically by the arrow 96, into the outlet header box 90 of the charge air cooler. Advantageously, the passage cross section placing the exhaust gas cooler in communication with the header box 90 is equal to or greater than the passage cross section of the bundle 4.

The inlet and outlet ducts 82 and 84 may be made of aluminum and brazed to the half-casings 7 and 8 during the single operation of brazing the cooling module. Alternatively, like the duct 82 in the example, they may be made of some other material, for example of plastic and mounted after the brazing operation. The embodiment of figures 14 to 18 can therefore be achieved in a single material, for example aluminum, which allows it to be assembled entirely in a single brazing operation without even having to add on the charge air cooler inlet and outlet header boxes as had to be done in the preceding examples.

One of the two half-casings, the half-casing 8 in the example, comprises a pressed housing 14 intended to accommodate the exhaust gas cooler heat exchange bundle 4. As already described earlier, one of the dimensions

of the pressed housing 14 matches the length of the plates of the bundle 4, while the other dimension is able to form, respectively at an inlet end and at an outlet end of the bundle 4, inlet 16 and outlet 18 header boxes for the recirculated exhaust gases. It goes without saying that, in an embodiment variant, the pressed housing 14 could be replaced by an added-on separate casing identical to the casing 76 described previously.